

The Effect of Auxiliary Winding Turn Distribution on the Current Characteristics of Single-Phase Capacitor Induction Motors

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Abstract. Auxiliary winding turn distribution is a rewinding parameter that may influence the operating characteristics of single-phase capacitor induction motors. This study aims to analyze differences in operating current resulting from two auxiliary winding turn distribution configurations. Experimental tests were conducted on a single-phase capacitor induction motor with a 16-slot stator using two configurations: Configuration A, with evenly distributed auxiliary winding turns, and Configuration B, with unevenly distributed turns. Current measurements were taken at three speed selector settings: low, medium, and high. The data were analyzed descriptively by comparing current magnitudes, variation patterns, and differences between configurations. The results showed that Configuration A produced currents of 0.12, 0.13, and 0.15 A, whereas Configuration B produced 0.26, 0.20, and 0.17 A at the corresponding settings. Current increased with speed selector position in Configuration A but decreased in Configuration B. The current differences between the configurations were 0.14, 0.07, and 0.02 A, respectively, with the largest difference occurring at the low setting. Under the tested conditions, Configuration A consistently exhibited lower operating current than Configuration B. These findings indicate that auxiliary winding turn distribution is associated with differences in current characteristics. However, current measurements alone are insufficient to establish overall motor efficiency, operational stability, or performance superiority without additional measurements and further testing.

Keywords: *Single-Phase Induction Motor, Auxiliary Winding, Turn Distribution, Rewinding, Operating Current.*

A. INTRODUCTION

Single-phase induction motors are widely used to drive low-power appliances, including fans, because of their relatively simple, robust construction and ease of maintenance (Santoso et al., 2018). In capacitor-type single-phase induction motors, the main and auxiliary windings work together to generate the magnetic field required for electromagnetic torque. The capacitor connected to the auxiliary winding creates a phase difference between the currents in the two windings, supporting the formation of a rotating magnetic field (Anthony & Erhaneli, 2020). Motor operating characteristics depend not only on supply voltage and load but also on winding configuration and electrical relationships between windings. Anthony and Erhaneli (2018) demonstrated that variations in main and auxiliary winding designs can produce different performance characteristics (Da Costa et al., 2025). Therefore, the number of turns, distribution of winding groups, and winding connections are important considerations in motor design and repair.

Rewinding is a common repair method for motors with damaged stator windings. Its success should be assessed not only by whether the motor operates again but also by its electrical characteristics after repair (Atabiq et al., 2018). Variations in turn count, wire

diameter, and winding arrangement may affect resistance, inductance, and circuit impedance. Hendrick and Liliana (2024) found that wire size and stator slot spacing were associated with changes in starting current in three-phase induction motors. Although their motor type and test conditions differed, their findings highlight the importance of winding parameters when evaluating current characteristics. In single-phase fan motors with multiple speed settings, the distribution of auxiliary winding turns among groups connected to the speed selector terminals warrants further investigation. Specifically, the relationship between uniform and nonuniform turn distributions and the magnitude and variation of operating current at low, medium, and high speed settings remains to be examined.

Previous studies have established the importance of winding configuration in induction motor performance. Santoso et al. (2018) compared stator winding types through modeling and experimental testing. Anthony and Erhaneli (2018) developed a single-phase induction motor with four nonidentical windings, comprising one main winding and three auxiliary windings, and evaluated its output power and efficiency (Zhang et al., 2025). They subsequently investigated adjustments to run-capacitor capacitance in this four-winding design to improve operating characteristics (Anthony & Erhaneli, 2020). Atabiq et al. (2018) evaluated the efficiency of three single-phase induction motors rated below 1 HP after rewinding and reported efficiency improvements in the tested motors. Meanwhile, Hendrick and Liliana (2024) examined the effects of wire size and stator slot spacing on the starting current of three-phase induction motors. Although these studies demonstrate that winding design and construction parameters influence electrical characteristics and motor performance, they address different configurations, variables, and objectives. Specifically, they focus on stator winding types, four-winding designs and capacitance adjustment, post-rewinding efficiency, and three-phase motor starting current, respectively (Miloudi et al., 2024). Direct comparisons of uniform and nonuniform auxiliary winding turn distributions in relation to line current across three speed selector settings have not been specifically addressed in these studies (Chakraborty et al., 2025). The relationship between winding groups connected to selector terminals, measured current, and equivalent input impedance also remains insufficiently examined under a common experimental framework (Adragna et al., 2024). This research gap motivates a comparative investigation of current magnitude and variation resulting from two auxiliary winding configurations.

This study aims to analyze differences in the operating current characteristics of capacitor-type single-phase induction motors by comparing two auxiliary winding turn distribution configurations: Configuration A, with uniform distribution, and Configuration B, with nonuniform distribution. Tests were conducted using two motors with equivalent specifications and 16-slot stators at a supply voltage of 220 V, under low, medium, and high speed settings. The analysis examined current magnitude, variation patterns, differences between configurations, and equivalent input impedance calculated from measured voltage and current. The study's novelty lies in its comparative approach linking auxiliary winding turn distribution, speed selector terminal mapping, and line current characteristics across the two tested winding configurations. Its contribution is comparative experimental data and equivalent input impedance analysis to support the evaluation of winding configurations in capacitor-type single-phase induction motors. However, the findings are limited to current characteristics and input impedance under the tested conditions, as the effect of winding distribution cannot be fully separated from potential differences between the two motors. Assessing overall efficiency and mechanical performance requires additional measurements and testing.

B. METHOD

1. Study Design

A single-phase capacitor induction motor is an electrical machine that uses a main winding and an auxiliary winding to generate a magnetic field that enables the production of electromagnetic torque on the rotor (Vadodariya et al., 2025). The two windings are positioned with a displacement between their magnetic axes on the stator. The main winding produces the main magnetic field component, whereas the auxiliary winding, which is connected to a capacitor, produces an additional field component with a phase difference between its current and that of the main winding. The interaction between these two field components produces a rotating magnetic field that enables the motor to start and operate. The characteristics of the magnetic field are influenced by the current magnitude, phase difference, and stator winding configuration (Santoso et al., 2018; Anthony & Erhaneli, 2020).

The capacitor in the auxiliary winding circuit provides capacitive reactance, which affects the phase relationship between voltage and current. The capacitive reactance is expressed in Equation (1).

$$\left[X_c = \frac{1}{2\pi f C} \right] \dots\dots\dots(1)$$

where (X_c) is the capacitive reactance (Ω), (f) is the power supply frequency (Hz), and (C) is the capacitance (F). Based on Equation (1), capacitive reactance is inversely proportional to the supply frequency and capacitance. At a constant frequency, a change in capacitance alters the capacitive reactance and may affect the auxiliary winding current and the motor's operating characteristics (Aldaikh et al., 2024). Anthony and Erhaneli (2020) demonstrated that adjusting the run-capacitor capacitance is associated with changes in the operating characteristics of single-phase induction motors. Therefore, capacitance is an important parameter that must be considered when testing winding configurations.

In a permanent split capacitor (PSC) motor, the auxiliary winding and run capacitor remain connected throughout motor operation. In contrast, in a capacitor-start motor, the auxiliary circuit is generally used during the starting process and is subsequently disconnected through a specific mechanism (Li et al., 2024). The distinction between these two motor types must be considered because it affects circuit connections and current characteristics during operation. In this study, the term *auxiliary winding* refers to the winding groups under investigation, while the classification of the capacitor circuit is based on the actual connections of the tested motor (Rüetschi & Gerdstigen, 2026).

2. Turn Distribution and Speed Selector Connections

In this study, the distribution of auxiliary winding turns is defined as the allocation of the total number of turns into three winding groups, namely S1, S2, and S3. This allocation represents the distribution of turns among winding groups and must be distinguished from the spatial distribution of the windings, which concerns the placement of coil sides in the stator slots, winding pitch, and orientation of the magnetic axes. Changes in winding configuration may affect the distribution of magnetomotive force and the motor's operating characteristics, as investigated by Santoso et al. (2018).

In general, the total number of auxiliary winding turns can be expressed using Equation (2).

$$\left[N_{b,tot} = \sum_{j=1}^m N_j \right] \dots\dots\dots(2)$$

where ($N_{b,tot}$) is the total number of auxiliary winding turns, (N_j) is the number of turns in winding group (j), and (m) is the number of winding groups.

Because the auxiliary winding in this study is divided into three groups, Equation (2) can be expressed as:

$$\left[N_{b,tot} = N_1 + N_2 + N_3 \right] \dots\dots\dots(3)$$

The turn distribution of each group can be expressed as a proportion of the total number of turns using Equation (4).

$$[p_j = \frac{N_j}{N_{b,tot}} \times 100] \dots\dots\dots(4)$$

where (p_j) is the proportion of turns in winding group (j) relative to the total number of auxiliary winding turns (%). In a configuration with a uniform turn distribution, each group has the same or approximately the same number of turns. Conversely, in a configuration with a nonuniform turn distribution, the number of turns differs among the groups. This study uses two auxiliary winding turn distribution configurations, as presented in Table 1.

Table 1. Distribution of Auxiliary Winding Turns in the Two Configurations

Winding Group	Configuration A (turns)	Configuration B (turns)
S1	317	475
S2	317	317
S3	317	158
Total	951	950

Based on Table 1, Configuration A uses a uniform turn distribution of 317 turns in each group, resulting in a total of 951 turns. Meanwhile, Configuration B uses a nonuniform distribution, comprising 475 turns in S1, 317 turns in S2, and 158 turns in S3, resulting in a total of 950 turns. The one-turn difference in the total number of turns needs to be verified against the actual winding records. Based on these totals, Configuration A has a proportion of approximately 33.33% in each group, whereas Configuration B has proportions of approximately 50.00% in S1, 33.37% in S2, and 16.63% in S3. In motors with multiple speed selector positions, winding groups are connected to terminals that can be selected through a switch. In this study, terminal T1, which is red, is used for the high-speed setting; terminal T2, which is white, is used for the medium-speed setting; and terminal T3, which is blue, is used for the low-speed setting. The relationship between the selector terminals and the winding groups is presented in Table 2.

Table 2. Mapping of Speed Selector Terminals and Auxiliary Winding Groups

Selector Position	Terminal	Associated Group	Configuration A (Turns)	Configuration B (Turns)
Low	T3 (Blue)	S3	317	158
Medium	T2 (White)	S2	317	317
High	T1 (Red)	S1	317	475

Note: The number of turns in Table 2 represents the number of turns in the group associated with the selected terminal, rather than the total effective number of turns carrying current at each switch position.

The number of turns electrically involved at a given selector position depends on the circuit connections among the winding groups, capacitor, and supply terminals. If several groups are connected in series with their magnetization directions reinforcing one another, the total number of series-connected turns can be expressed as:

$$[N_{seri,k} = \sum_{j \in S_k} N_j] \dots\dots\dots(5)$$

where ($N_{seri,k}$) is the total number of turns in the winding groups connected in series at selector position (k), while (S_k) is the set of winding groups connected in series at that position. Equation (5) applies only to groups connected in series and whose magnetization directions satisfy the stated assumption. It cannot be directly applied to groups connected in parallel or to groups with opposing magnetization directions. Therefore, determining the effective number of turns in this study requires identification of the motor's actual circuit connections. The terminal mapping in Table 2 serves as the basis for relating winding groups to selector positions without assuming that the other groups are disconnected from the circuit.

3. Relationship Between the Number of Turns and Winding Parameters

The number of turns is one of the construction parameters associated with winding resistance and inductance. Changes in turn distribution may affect conductor length and the electromagnetic characteristics of the winding groups. Therefore, an analysis of turn distribution must consider the electrical parameters and magnetic conditions of the motor. The resistance of a conductor can theoretically be expressed using Equation (6).

$$\left[R = \rho \frac{Nl_{rata}}{A_{Cu}} \right] \dots\dots\dots(6)$$

where (R) is the conductor resistance (Ω), (ρ) is the electrical resistivity of the conductor material ($\Omega \cdot m$), (N) is the number of turns, (l_{rata}) is the average conductor length per turn (m), and (A_{Cu}) is the cross-sectional area of the conductive metal (m^2).

For a circular conductor, the cross-sectional area can be calculated using Equation (7).

$$\left[A_{Cu} = \frac{\pi d^2}{4} \right] \dots\dots\dots(7)$$

where (d) is the diameter of the conductive metal, excluding its insulation layer (m).

Based on Equation (6), if the conductor material, wire diameter, temperature, and average length per turn are assumed to be identical, winding resistance is approximately proportional to the number of turns. Accordingly, the resistance ratio of winding group (j) in Configuration B to that in Configuration A can be estimated using Equation (8).

$$\left[\frac{R_{B,j}}{R_{A,j}} \approx \frac{N_{B,j}}{N_{A,j}} \right] \dots\dots\dots(8)$$

where ($R_{\{A,j\}}$) and ($R_{\{B,j\}}$) are the resistances of winding group (j) in Configurations A and B, respectively, while ($N_{\{A,j\}}$) and ($N_{\{B,j\}}$) are the corresponding numbers of turns in the two configurations. In addition to resistance, the number of turns is also related to winding inductance. Under a linear magnetic circuit approximation with constant reluctance, the relationship between inductance and the number of turns can be expressed using Equation (9).

$$\left[L \approx \frac{N^2}{R_m} \right] \dots\dots\dots(9)$$

where (L) is the inductance (H), (N) is the number of turns, and (R_m) is the magnetic circuit reluctance (A/Wb). If the effective magnetic reluctance is assumed to be identical, the inductance ratio of winding group (j) in Configuration B to that in Configuration A can be estimated using Equation (10).

$$\left[\frac{L_{B,j}}{L_{A,j}} \approx \left(\frac{N_{B,j}}{N_{A,j}} \right)^2 \right] \dots\dots\dots(10)$$

The relationships in Equations (8) and (10) are theoretical approximations based on the assumption that the conductor and magnetic circuit parameters are equivalent. In an actual induction motor, resistance may be affected by differences in average turn length and temperature, whereas inductance is influenced by coil geometry, leakage flux, magnetic saturation, and electromagnetic coupling with the rotor. Therefore, these two equations cannot be used to establish actual resistance or inductance values without direct measurements.

Hendrick and Liliana (2024) demonstrated that changes in wire parameters and winding arrangements are associated with the current characteristics of three-phase induction motors. Meanwhile, Santoso et al. (2018) highlighted the importance of winding configuration in the characteristics of single-phase induction motors. These two studies support the need to consider construction parameters and electromagnetic characteristics when evaluating the turn distribution of auxiliary windings.

4. Current Characteristics and Motor Input Impedance

The operating current of a single-phase capacitor induction motor is influenced by winding parameters, the capacitor circuit, supply voltage, rotor conditions, and mechanical loading. Therefore, changes in operating current cannot be explained solely by conductor resistance or the number of turns in a winding group. Studies on winding configurations and capacitance adjustment indicate that motor operating characteristics involve interactions among several electrical and electromagnetic parameters (Santoso et al., 2018; Anthony & Erhaneli, 2020).

In a circuit where the main and auxiliary windings form two parallel branches across the supply, the line current is the phasor sum of the currents in the two branches, as expressed in Equation (11).

$$[I_s = I_u + I_b] \dots\dots\dots(11)$$

where (I_s) is the line current phasor, (I_u) is the main winding current phasor, and (I_b) is the auxiliary winding current phasor. Equation (11) indicates that the line current is not necessarily equal to the arithmetic sum of the magnitudes of the currents in the two windings because of the difference in their phase angles. The application of this equation also depends on the motor's actual circuit configuration. Therefore, the current measurement location must be clearly specified to ensure that the data represent the same parameter in every test.

To evaluate the relationship between supply voltage and operating current, the magnitude of the motor's equivalent input impedance can be calculated using Equation (12).

$$[|Z_{in,k}| = \frac{V_{RMS,k}}{I_{RMS,k}}] \dots\dots\dots(12)$$

where $Z_{in,k}$ is the magnitude of the motor's equivalent input impedance at selector position (k) (Ω), $V_{RMS,k}$ is the root mean square (RMS) supply voltage (V), and $I_{RMS,k}$ is the RMS line current (A). In this study, the tests were conducted at a supply voltage of 220 V. Accordingly, the input impedance magnitude at each selector position can be calculated from this voltage and the line current measured during testing. Equivalent input impedance describes the relationship between the voltage and current observed at the motor's supply terminals under a specific operating condition. The value calculated using Equation (12) represents the magnitude of impedance, not pure resistance or winding inductance. Additional information about the phase angle between voltage and current or the power factor is required to separate the resistive and reactive components of impedance. The comparison of current characteristics between Configurations A and B is performed by calculating the current difference at the same selector position. The current difference is expressed using Equation (13).

$$[\Delta I_k = I_{B,k} - I_{A,k}] \dots\dots\dots(13)$$

where ΔI_k is the current difference between Configuration B and Configuration A at selector position (k) (A), while $I_{B,k}$ and $I_{A,k}$ are the line currents of the two configurations at the corresponding positions. To clarify the magnitude of the relative difference, the percentage current difference relative to Configuration A can be calculated using Equation (14).

$$[\delta_k = \frac{I_{B,k} - I_{A,k}}{I_{A,k}} \times 100] \dots\dots\dots(14)$$

where (δ_k) is the percentage current difference between Configuration B and Configuration A at selector position (k). A positive value indicates that the current in Configuration B is greater than that in Configuration A, whereas a negative value indicates the opposite. This percentage represents only the difference in line current and cannot be used as a measure of an increase or decrease in motor efficiency. Evaluating motor efficiency requires measurements of input power and mechanical output power, as addressed in the study by

Atabiq et al. (2018). Therefore, comparisons of current and input impedance cannot directly determine which winding configuration has better efficiency or mechanical performance.

Based on this theoretical foundation, the distribution of auxiliary winding turns may be associated with changes in the motor's electrical characteristics through resistance, inductance, circuit impedance, and electromagnetic interactions between windings. However, the quantitative relationship between the number of turns in each group and line current depends on the circuit configuration and the motor's operating conditions. Accordingly, this study adopts a comparative approach to examine operating current at three speed selector positions and calculate equivalent input impedance based on the available voltage and current data. The comparison results are used to identify observable differences in electrical characteristics, while explanations of the underlying physical mechanisms are limited to those supported by the experimental data.

C. METHOD

This study employed a comparative experimental method to analyze differences in the operating current characteristics of single-phase capacitor induction motors based on two auxiliary winding turn distribution configurations. The research objects consisted of two fan motors with equivalent specifications and 16-slot stators. Configuration A used a uniform distribution of auxiliary winding turns, whereas Configuration B used a nonuniform turn distribution. The tests were conducted at three speed selector positions, namely low, medium, and high, with a supply voltage of 220 V. The experimental design compared the operating currents of the two configurations at the same selector positions. Since each configuration was implemented on a different motor, the possible influence of differences in the physical and electromagnetic characteristics of the two motors was also considered when interpreting the results. Therefore, the analysis focused on the observed differences in current characteristics and was not intended to isolate winding distribution as the sole cause of current variations.

The motors used in this study were single-phase capacitor induction motors with 16-slot stators. According to the winding records, the specified wire diameter was 0.15 mm. The tests were conducted using a supply voltage of 220 V. The motor specifications, winding parameters, and test conditions are presented in Table 3.

Table 3. Motor Specifications and Test Conditions

Parameter	Description
Motor type	Single-phase capacitor induction motor
Test objects	Two fan motors
Number of stator slots	16 slots
Wire diameter	0.15 mm (based on the initial records)
Number of main winding turns	Not yet confirmed: 849 or 850 turns
Rated voltage	220 V
Rated frequency	50 Hz
Test voltage	220 V
Capacitor capacitance	Not yet reported
Loading condition	Not yet reported
Current measuring instrument	Model and accuracy not yet reported
Voltage measuring instrument	Model and accuracy not yet reported

The parameters that are not yet available need to be completed based on the equipment specifications and experimental records. This information is necessary to describe the test conditions and assess the equivalence of the two motors.

1. Auxiliary Winding Configurations

The configuration variations were implemented by distributing the number of auxiliary winding turns among groups S1, S2, and S3. Configuration A used the same number of turns in each group, namely 317 turns. Configuration B used a nonuniform distribution, comprising 475 turns in S1, 317 turns in S2, and 158 turns in S3.

Table 4. Distribution of auxiliary winding turns

Winding Group	Configuration A (turns)	Configuration B (turns)
S1	317	475
S2	317	317
S3	317	158
Total	951	950

The differences in turn distribution are illustrated by the Configuration A and Configuration B diagrams in Figures 1 and 2. Both diagrams illustrate the allocation of turns and the connections between the winding groups and the speed selector terminals.

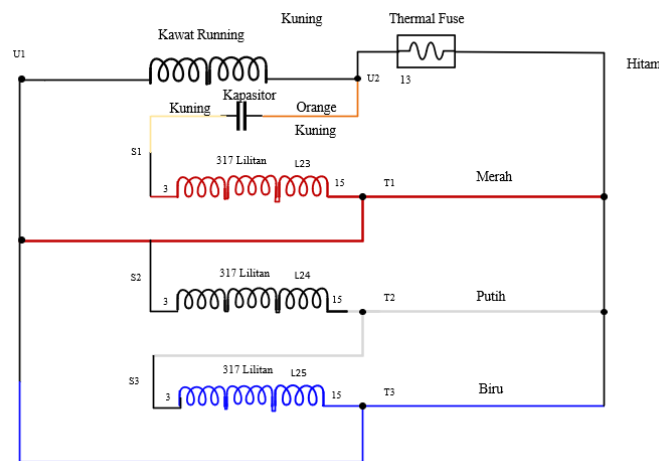


Figure 1. Diagram of the Auxiliary Winding Turn Distribution in Configuration A

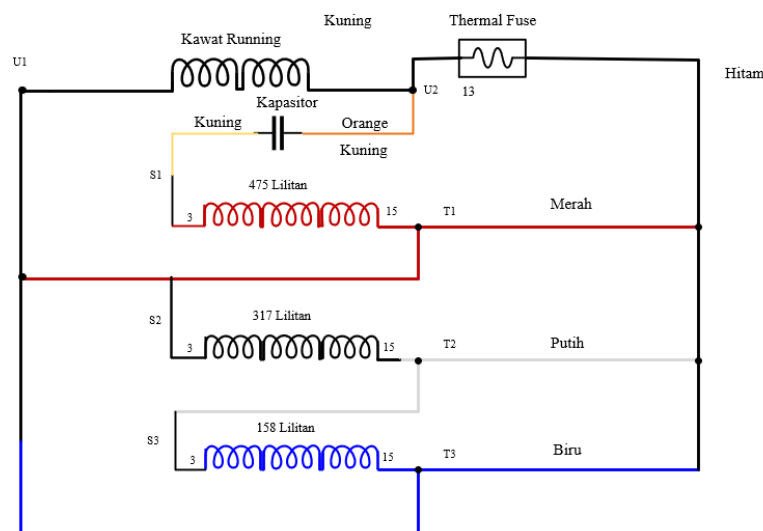


Figure 2. Diagram of the Auxiliary Winding Turn Distribution in Configuration B

Terminal T1 (red) was used for the high-speed setting, terminal T2 (white) for the medium-speed setting, and terminal T3 (blue) for the low-speed setting. The relationship between each terminal and its associated winding group is presented in Table 5.

Table 5. Relationship Between Speed Selector Terminals and Auxiliary Winding Groups

Selector Position	Terminal	Associated Group	Configuration A (turns)	Configuration B (turns)
Low	T3 (Blue)	S3	317	158
Medium	T2 (White)	S2	317	317
High	T1 (Red)	S1	317	475

The number of turns presented in Table 5 represents the winding group associated with each selector terminal. These values are not directly interpreted as the effective number of turns in the circuit because this depends on the electrical connections among the winding groups. The total number of turns in Configurations A and B differs by one turn; therefore, these values need to be verified against the actual winding records.

2. Research Variables

The independent variable in this study was the auxiliary winding turn distribution configuration, consisting of uniform and nonuniform distributions. The low, medium, and high speed selector positions were used as test condition factors. The primary dependent variable was the motor operating current measured at each speed selector position. In addition to operating current, the study used the magnitude of equivalent input impedance as a calculated outcome parameter based on voltage and current. Other parameters, including wire diameter, main winding characteristics, capacitor value, supply frequency, loading condition, and the physical condition of the motors, need to be documented to evaluate the equivalence of the test conditions. The test supply voltage was set at 220 V, while the equivalence of the other parameters was assessed based on the specifications and actual conditions of the two motors.

3. Testing Procedure

The testing process began with an inspection of the motor condition, winding configuration, capacitor, and speed selector terminal connections. Before operation, the power supply and measuring instruments were prepared according to the measurement requirements. The motor current was measured using an instrument placed at [to be confirmed: the supply line or winding branch], while the supply voltage was checked at the motor input terminals. Testing was conducted at a supply voltage of 220 V for each configuration. The motors were operated alternately at the low, medium, and high selector positions. Current readings were recorded after the motor reached a steady operating condition, as defined by [complete using the actual criterion]. The same procedure was applied to both motors while maintaining equivalent test conditions as far as practicable.

The number of measurement repetitions was [complete based on the actual experimental records]. The data used in the analysis consisted of the measured current values at each selector position. Voltage, rotational speed, and other parameters were reported as experimental results only if they had actually been measured.

4. Data Processing and Analysis

The experimental data were analyzed using a descriptive comparative approach by comparing the operating currents of Configurations A and B at the same speed selector positions. The analysis considered current magnitude, current variation across selector positions, current differences, and the percentage difference relative to Configuration A. The current difference was calculated using Equation (13), while the percentage relative difference was calculated using Equation (14). In addition, the magnitude of equivalent input

impedance was calculated using the test voltage of 220 V and the current measured under each condition, based on Equation (12). This calculation was used to characterize the relationship between voltage and current at the motor input terminals, rather than to determine the resistance or inductance of individual winding groups.

The processed results were presented in tables and graphs to illustrate differences in current characteristics and input impedance between the two configurations. The analysis was limited to the available measurement data and calculated results, without drawing conclusions about the overall efficiency or mechanical performance of the motors.

D. RESULT AND DISCUSSION

1. Current Measurement Results for Both Configurations

The single-phase capacitor induction motors were tested at a supply voltage of 220 V by comparing two auxiliary winding turn distribution configurations. Configuration A used a uniform turn distribution, whereas Configuration B used a nonuniform turn distribution. The tests were conducted at three speed selector positions, namely low, medium, and high. The test results showed that Configuration A produced currents of 0.12 A, 0.13 A, and 0.15 A, whereas Configuration B produced currents of 0.26 A, 0.20 A, and 0.17 A at the corresponding selector positions. The current comparison between the two configurations is presented in Table 6.

Table 6. Comparison of Motor Operating Current Between the Two Configurations

Selector Position	Current A (A)	Current B (A)	Difference B–A (A)	Difference (%)
Low	0.12	0.26	0.14	116.67
Medium	0.13	0.20	0.07	53.85
High	0.15	0.17	0.02	13.33

Based on Table 6, Configuration B produced a higher current than Configuration A at all selector positions. The largest current difference occurred at the low-speed position, amounting to 0.14 A or 116.67% relative to Configuration A. This difference decreased to 0.07 A at the medium-speed position and 0.02 A at the high-speed position. The percentage differences were calculated using Configuration A as the reference, in accordance with Equation (14). These results reveal an observable difference in current magnitude between the two configurations. However, the data represent the available measurement values and have not been identified as averages from repeated tests.

2. Comparison of Current Variation Patterns

The current variation patterns of the two configurations are presented in Figure 3. The graph was constructed based on measurements taken at the low, medium, and high-speed selector positions.

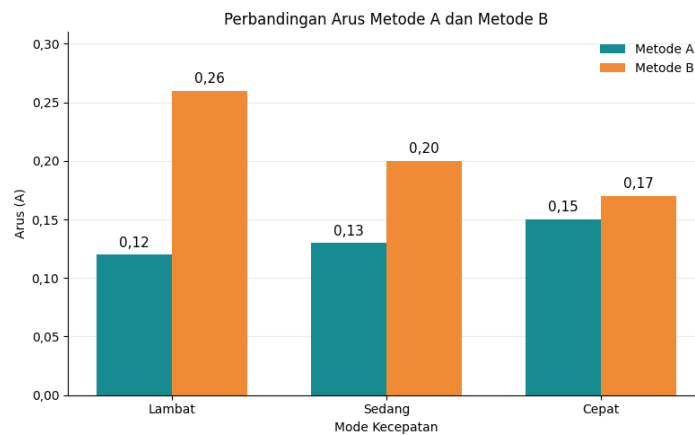


Figure 3. Comparison of Operating Current Between Configurations A and B at Three Speed Selector Positions

Based on Figure 3, Configuration A exhibited an increasing current trend, from 0.12 A at the low-speed position to 0.15 A at the high-speed position. The total current increase was 0.03 A, or 25.00% relative to the low-speed position. Conversely, Configuration B exhibited a decreasing current trend, from 0.26 A to 0.17 A, with a total decrease of 0.09 A, or 34.62% relative to the low-speed position. The differences in these trends indicate that the two configurations exhibited opposing current response patterns as the selector position changed. In Configuration A, a higher selector position was associated with a higher measured current, whereas Configuration B exhibited the opposite trend. In this study, the terms low, medium, and high refer to the speed selector switch positions and not to actual measurements of rotor speed. Anthony et al. (2022) reported that changes in the winding design of single-phase induction motors can produce differences in performance characteristics, including power factor, torque, output power, and efficiency in the motors they tested. Their study supports the importance of winding configuration when evaluating motor operation. However, their findings cannot be directly compared with the current data in this study because of differences in design and testing parameters.

3. Effect of Turn Distribution on Current Characteristics

The distribution of auxiliary winding turns was analyzed based on the relationship between winding groups S1, S2, and S3 and the speed selector terminals. In the tested motors, terminal T3 (blue) was used for the low-speed position, T2 (white) for the medium-speed position, and T1 (red) for the high-speed position. The relationship between the number of turns in each group and the measured current is presented in Table 7.

Table 7. Relationship Between Auxiliary Winding Groups, Number of Turns, and Operating Current

Position	Associated Group	Configuration A (turns)	Configuration B (turns)	Current A (A)	Current B (A)
Low	S3	317	158	0.12	0.26
Medium	S2	317	317	0.13	0.20
High	S1	317	475	0.15	0.17

Note: The number of turns represents the number of turns in the group associated with the selector terminal, rather than the total number of effective turns in the entire circuit.

Table 7 shows that in Configuration A, each winding group has the same number of turns, namely 317, but the operating current increases as the selector position changes from low to high. In Configuration B, the number of turns in the associated group increases from 158 to 475, while the measured current decreases from 0.26 A to 0.17 A.

Theoretically, the number of turns is related to the resistance and inductance of the winding groups, as expressed in Equations (8) and (10). Assuming equivalent wire material, cross-sectional area, average turn length, and magnetic circuit characteristics, the resistance ratio is estimated to be proportional to the turn ratio, whereas the inductance ratio is estimated to be proportional to the square of the turn ratio.

Table 8. Theoretical Comparison of Resistance and Inductance Ratios of the Winding Groups

Group	Turn Ratio B/A	Resistance Ratio B/A	Inductance Ratio B/A
S3 (low)	0.498	0.498	0.248
S2 (medium)	1.000	1.000	1.000
S1 (high)	1.498	1.498	2.245

The values in Table 8 are relative theoretical estimates based on the number of turns, rather than measurements of actual resistance or inductance. In group S3, Configuration B has fewer turns than Configuration A; therefore, its theoretical resistance and inductance are estimated to be lower under the stated assumptions. Conversely, in group S1, Configuration B has more turns, resulting in higher theoretical resistance and inductance ratios. These trends provide a basis for inferring potential differences in the electrical parameters of the winding groups. However, the motor line current is influenced by the overall circuit connections, capacitor, electromagnetic coupling, and rotor operating conditions. Therefore, differences in current patterns cannot be explained solely by changes in the resistance and inductance of a single winding group. This is also evident at the medium-speed position. Although winding group S2 in Configurations A and B has the same number of turns, namely 317, the measured currents differ, at 0.13 A and 0.20 A, respectively. This condition indicates that an identical number of turns in the associated group does not guarantee an identical motor current. Differences in the overall circuit characteristics and the physical conditions of the two motors may still contribute to the measured results.

Hendrick and Liliana (2024) demonstrated a relationship between winding construction parameters and starting current characteristics in three-phase induction motors. Meanwhile, Akbari Resketi et al. (2023) evaluated changes in winding topology using winding function analysis, modeling, and testing to investigate the electromagnetic characteristics of motors. These studies support the need to consider winding configurations and electromagnetic parameters comprehensively, although their research objects and test conditions differ from those of the present study.

4. Analysis of Equivalent Input Impedance

In addition to comparing operating current, the magnitude of equivalent input impedance was calculated based on the test voltage of 220 V and the current data. The calculation used Equation (12), assuming that the current values represented the line current measured at the motor input terminals. The calculated input impedance values for both configurations are presented in Table 9.

Table 9. Calculated Equivalent Input Impedance Magnitudes at A Voltage Of 220 V

Position	Current A (A)	Impedance A (Ω)	Current B (A)	Impedance B (Ω)
Low	0.12	1,833.33	0.26	846.15
Medium	0.13	1,692.31	0.20	1,100.00
High	0.15	1,466.67	0.17	1,294.12

Based on Table 9, the input impedance magnitude of Configuration A decreased from 1,833.33 Ω at the low-speed position to 1,466.67 Ω at the high-speed position. Conversely,

Configuration B showed an increase in input impedance magnitude from $846.15\ \Omega$ to $1,294.12\ \Omega$. At the same test voltage, a decrease in input impedance magnitude is directly associated with an increase in current, whereas an increase in impedance magnitude is associated with a decrease in current. Therefore, the impedance patterns of the two configurations are opposite to the respective current patterns of each configuration. However, the impedance values in Table 9 were calculated from voltage and current and therefore cannot be considered independent measurement evidence of changes in the electromagnetic characteristics of the motors. These values also do not separate the resistance and reactance components. Measurements of power factor or the phase angle between voltage and current, as well as winding parameters, are required for a more comprehensive impedance analysis. Thus, the calculated input impedance is used as a derived parameter describing the electrical characteristics at each test position. This analysis is not used to conclude that the impedance differences are entirely caused by changes in the number of auxiliary winding turns.

5. Interpretation of Results and Research Limitations

The test results indicate that Configuration A had a lower operating current than Configuration B at all speed selector positions. Configuration A also exhibited an increasing current pattern from the low-speed position to the high-speed position, whereas Configuration B showed a decreasing pattern. These differences in patterns are associated with the implementation of two auxiliary winding turn distribution configurations in the tested motors. Nevertheless, a lower current value does not directly indicate higher efficiency or better mechanical performance. Evaluating efficiency requires measurements of active input power and mechanical output power. Anthony et al. (2022) and Akbari Resketi et al. (2023) evaluated motor characteristics using several performance parameters, making their approaches broader than the current data available in this study.

This study has several limitations. First, the tests used two different motors, meaning that differences in their physical or electromagnetic characteristics may have affected the results. Second, repeated measurement data were not available to evaluate measurement variability and repeatability. Third, resistance, inductance, power factor, rotational speed, and active power data were not available to verify the physical mechanisms underlying the current variations. In addition, the total number of turns in the two configurations differed by one turn, and the internal connections between winding groups still require verification.

The input impedance magnitude calculated in this study is a derived parameter obtained from voltage and current. Therefore, the results cannot be used to determine the motor's resistance, inductance, or efficiency directly. Given these conditions, the findings are limited to comparisons of current magnitude, current variation patterns, relative differences, and equivalent input impedance magnitude derived from the test data. These findings provide preliminary information about differences in the electrical characteristics of the two configurations. However, they are insufficient to establish the dominant physical causes or determine the best winding configuration in terms of overall motor performance.

E. CONCLUSION

Testing of single-phase capacitor induction motors with 16-slot stators at a voltage of 220 V revealed differences in current characteristics between Configuration A, which used a uniform auxiliary winding turn distribution, and Configuration B, which used a nonuniform distribution. At the low, medium, and high-speed selector positions, the currents in Configuration A were 0.12, 0.13, and 0.15 A, respectively, whereas those in Configuration B were 0.26, 0.20, and 0.17 A. The current in Configuration A increased toward the high-speed

position, whereas that in Configuration B decreased, with the largest difference of 0.14 A occurring at the low-speed position.

At a voltage of 220 V, the equivalent input impedance magnitude calculated from the line current of Configuration A decreased from 1,833.33 Ω to 1,466.67 Ω , whereas that of Configuration B increased from 846.15 Ω to 1,294.12 Ω . These results indicate differences in the electrical characteristics of the two configurations. However, the effect of turn distribution cannot yet be established independently because the tests were conducted using two different motors. Therefore, verification of the winding connections and additional parameter measurements are required to explain the mechanisms underlying the current variations and evaluate the overall motor performance.

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